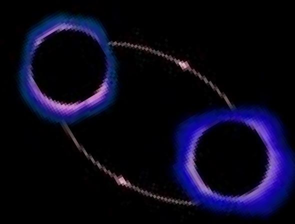
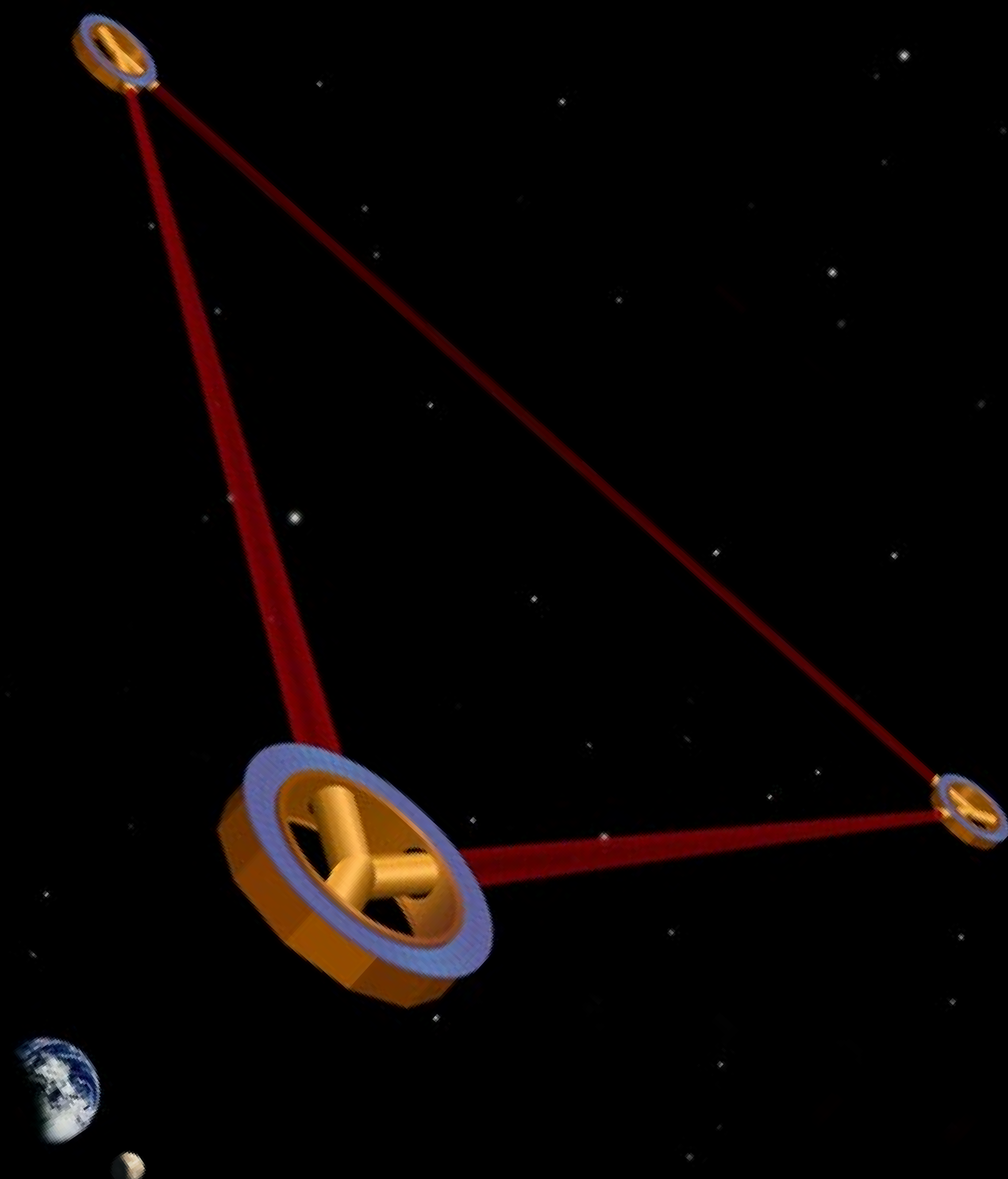
LISA

Recording the Gravitational-Wave Symphony of the Universe

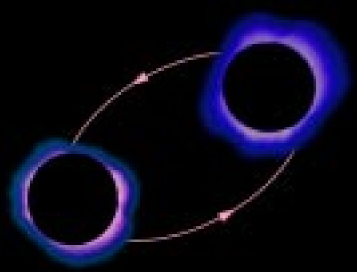


Laser Interferometer Space Antenna

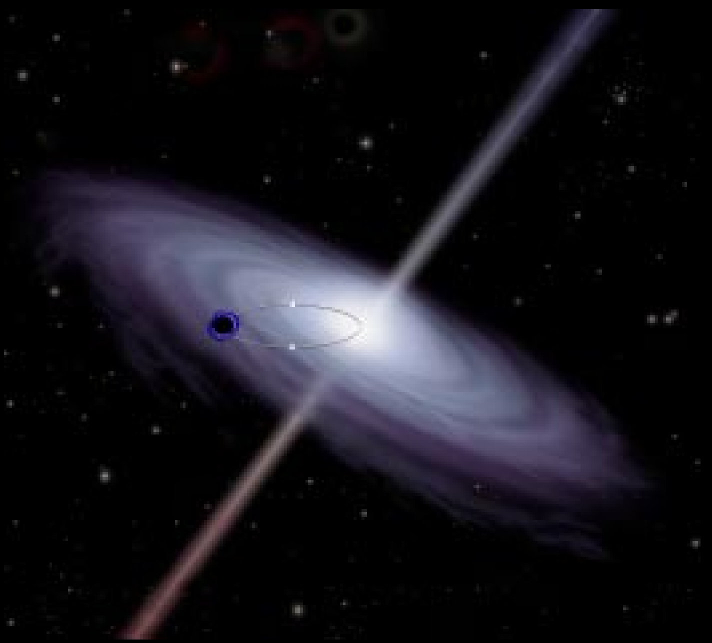
LISA's main objective is the detection and study of gravitational waves from sources involving massive black holes throughout the universe. These observations will provide unique new information on the space density, mass distribution, formation, and surroundings of massive black holes. LISA will also observe signals from thousands of compact binary star systems in the Milky Way. The signals from massive black holes and compact binaries will form a suite of constantly changing tones, the gravitational-wave symphony of the universe.



LISA will observe gravitational waves from:



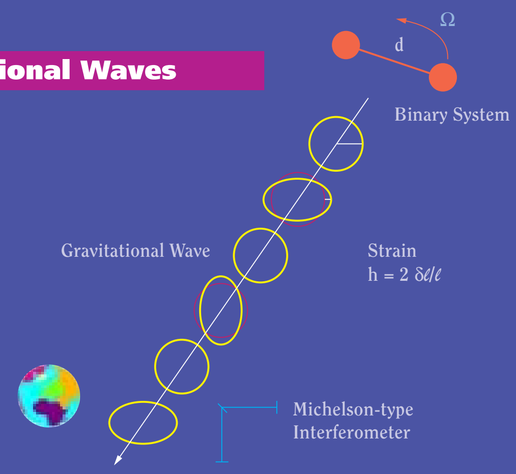
. . . the coalescences of massive black holes that result from the merging of galaxies.



. . . stellar-mass black holes inspiraling to massive black holes. (LISA will be probing conditions in galactic cusps, and providing precision, high-field tests of gravitational theory.)

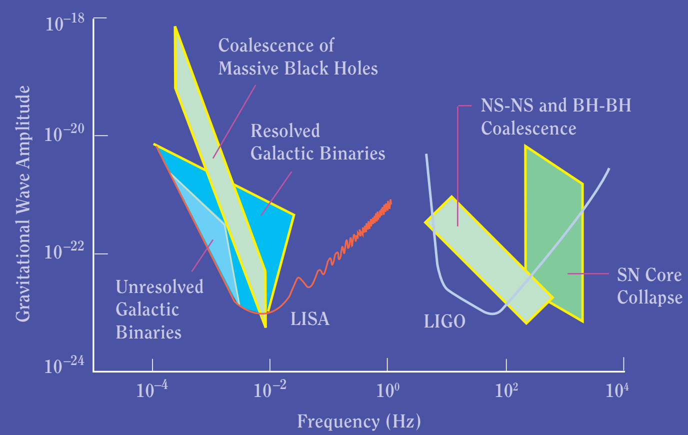
. . . thousands of compact binary star systems, including several known systems. Some will contain black holes or neutron stars.

Gravitational Waves



Gravitational waves are propagating gravitational fields, “ripples” in the curvature of space-time, generated by the motion of massive objects. Gravitational waves create a time-varying strain of space-time, which appears as a fractional change in the distance between any two points. Gravitational waves can be detected by devices which monitor the separation of proof masses — the greater the separation, the greater the measured displacement. The waveform is determined by the motion of the source masses. The direction to the source can be inferred from the amplitude and phase variation caused by LISA’s orbital motion.

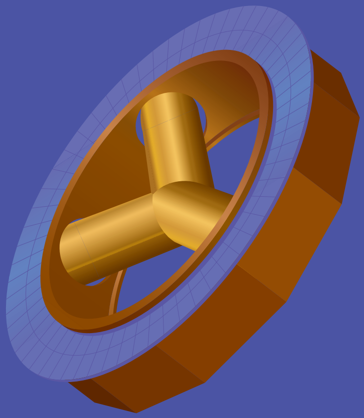
Ground and Space Detectors



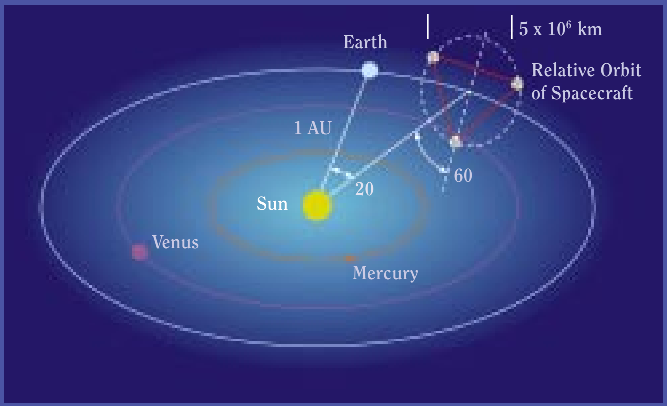
LISA will search for low-frequency gravitational waves which will never be detectable by any terrestrial detectors, existing or planned. These low-frequency gravitational waves cannot be detected on Earth because the Earth’s gravitational field is constantly changing (due to atmospheric effects and ground motions). These changes cause motion of proof masses in a way which is indistinguishable from the motion caused by gravitational waves. Ground-based detectors like the Laser Interferometer Gravitational-Wave Observatory (LIGO) will view the high-frequency waves from transient phenomena, like supernovae and the final minutes of inspiraling neutron-star binaries. LISA will observe the lower frequency waves from quasi-periodic sources, like compact star binaries long before coalescence, and supermassive black-hole binaries in the final months of coalescence.

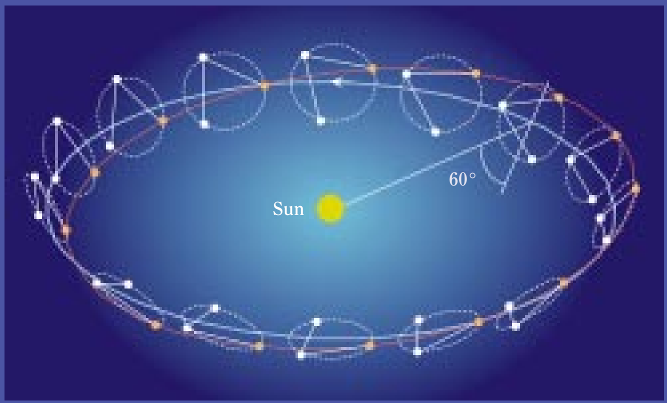
The Spacecraft

The LISA spacecraft is based on a short cylinder 1.8 meters in diameter and 0.5 meter high. The cylinder supports a Y-shaped tubular structure that contains two instruments. During science operations, the Sun will be 30 degrees from the normal to the top of the cylinder. Solar panels will be mounted on a sunshield that extends out from the top of the structural cylinder and keeps sunlight off the cylinder wall. A cover across the top of the cylinder (not shown) will prevent sunlight from striking the Y-shaped structure. The Y-shaped structure is gold-coated and suspended by stressed-fiberglass bands to thermally isolate it from the spacecraft. The spacecraft and Y-shaped structure are made of a graphite-epoxy composite chosen for its low coefficient of thermal expansion. Two 30-centimeter-diameter X-band radio antennas (not shown) will be mounted to the outside of the spacecraft for communication to Earth.



The Orbits

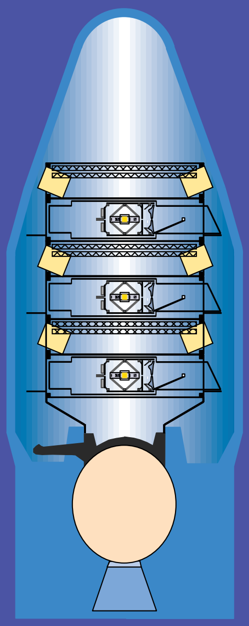


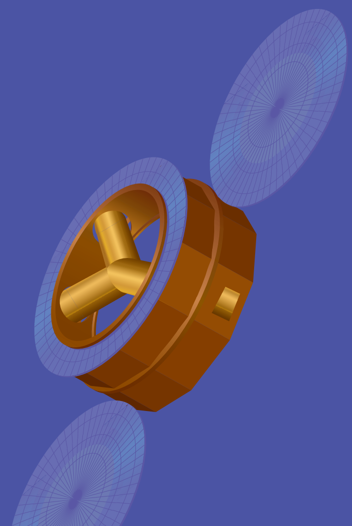


The LISA orbits are chosen to minimize changes in the distances between spacecraft. Each spacecraft will be in an Earth-like orbit around the Sun (top figure, above) with a period of one year. The spacecraft orbits will be slightly elliptical and slightly tilted with respect to each other and with respect to the plane of the Earth's orbit (the ecliptic). The spacecraft will maintain a triangular configuration even though each will be separately orbiting about the Sun. The bottom figure highlights the motion of one of the spacecraft and indicates how the distance between spacecraft remains the same and how the triangular formation changes orientation over one year. The changing orientation makes it possible to determine the direction of a gravitational wave source.

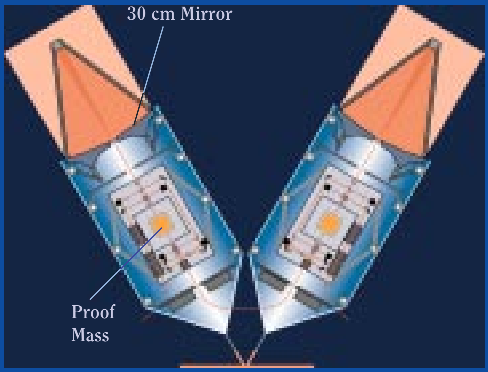
Launch and Orbit Transfer

A single launch vehicle will inject the three spacecraft into an Earth escape trajectory, causing the spacecraft to slowly drift behind Earth. After launch, the three spacecraft will separate from the launch vehicle and from each other. A solar-electric propulsion module will be used to transfer each spacecraft to its final orbit. The power for the solar-electric engines will be generated by two circular solar arrays that will be stored within the propulsion module at launch and then deployed to power the engine. Upon reaching the final orbits, about 13 months after launch, the propulsion modules will be separated from the spacecraft. The spacecraft positions then will evolve under gravitational forces only, with the spacecraft controlled locally in a "drag-free" manner to keep their positions centered about the proof masses contained within them.



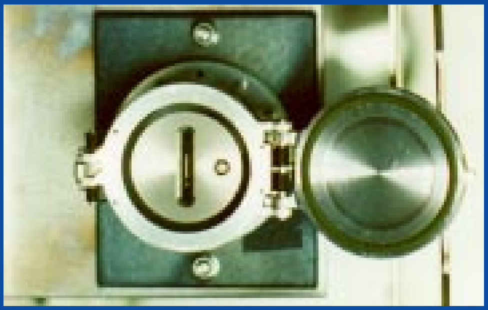


LISA Instrumentation and Technology



Each LISA spacecraft contains two instruments. Each instrument includes a 30-centimeter-diameter telescope for transmission and reception of laser signals from another spacecraft. Each instrument also has an optical bench that contains interferometer optics. An inertial sensor is mounted at the center of each optical bench, containing a proof mass shielded from nongravitational disturbances and a capacitor plate arrangement for measuring the position of the spacecraft with respect to the proof mass. The interferometer measures changes in the distance between proof masses in the different spacecraft. The spacecraft is kept centered on the proof masses, based on the capacitive sensors.

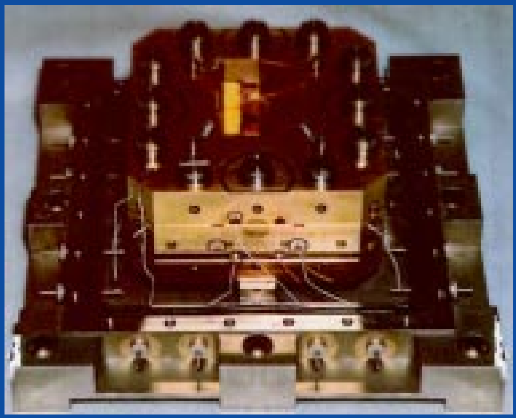
Micronewton Thrusters



Micronewton thruster developed by Centrospazio.

The LISA spacecraft positions must be precisely controlled to follow the motion of the proof masses. This requires thrusters for the spacecraft that can counteract the force due to sunlight with a position accuracy of 10 nanometers. Candidate thrusters, originally conceived for attitude control for communications satellites, have been under development in Europe. Liquid cesium or indium from small reservoirs is ionized and accelerated electrically to efficiently provide thrust that can be very finely controlled by adjustment of the acceleration voltage.

More information about LISA can be found at http://lisa.jpl.nasa.gov



Accelerometer developed by France's National Office for Aerospace Studies and Research (Office National d'Études et de Recherches Aérospatiales — ONERA).

Inertial Sensors

LISA requires proof masses that have extremely low levels of disturbances. LISA builds on experience with recent efforts to develop accelerometers for other space missions, such as the Gravity Probe B and GRACE (Gravity Recovery and Climate Experiment) missions. LISA requires much lower levels of disturbances than other missions, which can be achieved by a more benign orbit, changes in the geometry of the inertial sensor, and the use of a laser interferometer readout.

Infrared laser under test for the Space Interferometry Mission.

Laser Interferometry

LISA will measure the distance between proof masses separated by 5 million kilometers with an accuracy of 10 picometers. The large separation requires an appropriately sized laser and telescope. The distance uncertainty, which is very small compared with typical spacecraft measurements, is in fact much coarser than has already been demonstrated for ground-based gravitational-wave detectors.

The Jet Propulsion Laboratory (JPL), California Institute of Technology, manages LISA-related activities within the United States for the National Aeronautics and Space Administration's (NASA's) Structure and Evolution of the Universe Program. LISA-related activities within Europe are sponsored by the European Space Agency.

National Aeronautics and Space Administration

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